

CLAIMS

1. A semiconductor device comprising a semiconductor element having electrodes, and metal bumps including cores and metal surface layers covering said cores, said metal bumps being attached to the electrodes of said semiconductor element.

5. A semiconductor device according to claim 1, wherein said metal surface layer comprises one of gold and solder.

10. A semiconductor device according to claim 1, wherein said metal surface layer is a plated layer plated on said core.

15. A semiconductor device according to claim 1, wherein said core comprises one of a metal, an inorganic material and an organic material and has a diameter of not larger than 100  $\mu\text{m}$ , and said metal surface layer has a thickness of not larger than 50  $\mu\text{m}$ .

20. A semiconductor device according to claim 1, further comprising a wiring board having electrodes, said metal bumps attached to the electrodes of said semiconductor element being connected to the electrodes of said wiring board.

25. A semiconductor device comprising a semiconductor element having electrodes, and metal bumps comprising gold bump elements and solder bump elements connected together, said gold bump elements being attached to the electrodes of said semiconductor element.

30. A semiconductor device according to claim 6, wherein said gold bump element has a first side and a second side opposite to said first side, the first side of said gold bump element being joined to the electrode of the semiconductor element, and the second side of said gold bump element is joined to said solder bump element.

35. A semiconductor device according to claim 7, wherein the second side of said gold bump element forms a flat surface or a flat surface with a recessed portion.

9. A semiconductor device according to claim 1,

further comprising a wiring board having electrodes, the metal bumps attached to the electrodes of said semiconductor element being connected to the electrodes of said wiring board.

5 10. A semiconductor device comprising a semiconductor element having electrodes, and metal bumps comprising gold-containing solder films formed on the electrodes of said semiconductor element and metal bump elements provided on said gold-containing solder films.

10 11. A semiconductor device according to claim 10, further comprising a wiring board having electrodes, the metal bumps attached to the electrodes of said semiconductor element being connected to the electrodes of said wiring board.

15 12. A semiconductor device according to claim 10, wherein said metal bump element comprises one of gold and solder.

20 13. A semiconductor device according to claim 10, wherein said metal bump element is formed as one of a metal film and a metal ball.

25 14. A method of producing semiconductor devices, said method comprising the steps of: immersing a semiconductor element having electrodes in a molten gold-containing solder to form gold-containing solder films on the electrodes of said semiconductor element; and forming metal bump elements on said gold-containing solder films to thereby form metal bumps comprising said gold-containing solder films and said metal bump elements.

30 15. A method of producing semiconductor devices according to claim 14, wherein the step of forming the metal bump elements on said gold-containing solder films comprises immersing the gold-containing solder films in the molten solder to form solder films.

35 16. A method of producing semiconductor devices according to claim 14, wherein the step of forming the metal bump elements on said gold-containing solder films comprises immersing the gold-containing solder films in a

bath of molten metal.

17. A method of producing semiconductor devices according to claim 14, wherein the step of forming the metal bump elements on said gold-containing solder films comprises joining solid metal pieces onto the gold-containing solder films.

18. A method of producing semiconductor devices according to claim 14, further comprising the step of performing a process for imparting a fluxing action to the electrodes of the semiconductor element prior to immersing the semiconductor element having the electrodes in the molten gold-containing solder.

19. A method of producing semiconductor devices accord to claim 18, wherein the step of performing the process for imparting said fluxing action comprises irradiating the semiconductor element with a plasma.

20. A method of producing semiconductor devices according to claim 19, wherein the step of performing the process for imparting said fluxing action comprises cleaning the electrodes of the semiconductor element with a first gas, and forming a compound of a material of the electrodes of the semiconductor element and of a second gas.

21. A semiconductor device comprising a semiconductor element having electrodes, and metal bumps including gold bump elements having nose-like projections provided on the electrodes of said semiconductor element and solder elements formed on said gold bump elements to cover said projections.

22. A semiconductor device according to claim 21, further comprising a wiring board having electrodes, the metal bumps attached to the electrodes of said semiconductor element being connected to the electrodes of the wiring board.

23. A semiconductor device comprising a semiconductor element having electrodes, and metal bumps including gold bump elements provided on the electrodes

of said semiconductor element and first metal layers formed around said gold bump elements to protect said gold bump elements.

5 24. A semiconductor device according to claim 23, wherein said first metal layer has a melting point lower than a melting point of said gold bump element.

25 25. A semiconductor device according to claim 23, wherein a second metal layer is formed around said first metal layer.

10 26. A semiconductor device according to claim 24, wherein said second metal layer has a melting point which is lower than the melting point of said first metal layer by more than 20°C.

15 27. A semiconductor device according to claim 23, further comprising a wiring board having electrodes, the metal bumps attached to the electrodes of said semiconductor element being connected to the electrodes of the wiring board.

20 28. A method of producing semiconductor devices, comprising the steps of: attaching gold bump elements to electrodes of a semiconductor element; immersing said semiconductor element in a bath containing a molten amalgam of a mixture of a metal for protecting gold and of mercury to form an amalgam layer on said gold bump elements; heating said semiconductor element to vaporize the mercury in the amalgam and to form metal films on the gold bump elements to protect gold, and transferring molten solder elements to said metal films.

25 29. A method of producing semiconductor devices, comprising the steps of: attaching gold bump elements to electrodes of a semiconductor element; and transferring molten solder elements to said gold bump elements in an environment containing inert gas at an oxygen concentration of not higher than 10000 ppm.

30 35 30. A method of producing semiconductor devices according to claim 29, wherein at least one of alcohol, ketone, ester, ether and a mixture thereof is used as a

fluxing agent for transferring prior to transferring the molten solder elements.

5       31. A method of producing semiconductor devices according to claim 30, wherein said fluxing agent for transferring comprises a flux obtained by mixing a solid component thereof in an amount of not larger than 10% by weight in an alcohol.

10      Sub B1 > 32. An apparatus for producing semiconductor devices comprising: a booth; a molten-solder vessel arranged in said booth so that gold bump elements provided on the electrodes of a semiconductor element can be immersed in said vessel, means for supplying inert gas into said booth; and means for detecting the oxygen concentration in said booth.

15      33. An apparatus for producing semiconductor devices according to claim 32, further comprising a flux vessel for transferring disposed in said booth.

20      Sub B2 > 34. An apparatus for producing semiconductor devices comprising a molten-solder vessel arranged so that gold bump elements provided on the electrodes of a semiconductor element can be immersed in said vessel, and a support structure for hanging said semiconductor element, said support structure including a hanging mechanism comprising at least two mutually movably coupled coupling members.

25      35. An apparatus for producing semiconductor devices according to claim 34, wherein said at least two coupling members comprise members that are coupled together as in a chain.

30      36. An apparatus for producing semiconductor devices comprising a molten-solder vessel arranged so that gold bump elements provided on the electrodes of a semiconductor element can be immersed in said vessel, and a support structure for holding said semiconductor element, said support structure including a pump-type adsorption head having an open suction hole for holding the semiconductor element.

963 > 37. An apparatus for producing semiconductor devices comprising a molten-solder vessel arranged so that gold bump elements provided on the electrodes of a semiconductor element can be immersed in said vessel, and  
5 a support structure for holding said semiconductor element, said support structure including a holding mechanism comprising at least two mutually movably coupled coupling members and a pump-type adsorption head having an open suction hole for holding the semiconductor  
10 element.